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BIOTECHNOLOGY LABORATORY

PROGRESS REPORT

March 15, 1963

UPPER EXTREMITY PROSTHETICS RESEARCH

(Contract V1005M-2075 with U. S. Veterans Administration)

HUMAN TRACKING

(Contract N123(60530)23558A with U.S. Naval Ordnance)

SENSORY-MOTOR CONTROL

(Grant OVR RD-1201M-63)

Project Leader: John Lyman
Associate Professor of
Engineering and Psychology
Head, Biotechnology Laboratory

Engineering Dept. Report 63-17

DEPARTMENT OF ENGINEERING
University of California
Los Angeles

FOREWORD

The research described in this Biotechnology Laboratory Progress Report was carried out under the technical direction of John Lyman and is part of the continuing programs in Upper Extremity Prosthetics Research, Human Tracking and Sensory-Motor Control Research.

The Biotechnology Laboratory is part of the Department of Engineering of the University of California, Los Angeles. L. M. K. Boelter is Dean of the College of Engineering and Philip F. O'Brien acts as his representative for research activities.

BIOTECHNOLOGY LABORATORY STAFF

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UPPER EXTREMITY PROSTHETICS RESEARCH

Sponsor: U. S. Veterans Administration

I. FUNDAMENTAL STUDIES TO ESTABLISH BODY CONTROL SITES FOR APPLICATION TO EXTERNALLY-POWERED PROSTHESES

A. Objective

To conduct studies which will permit an evaluation of the practical feasibility of surgical and non-surgical methods for providing severely handicapped amputees with satisfactory body control sites. Such control sites must be capable of permitting coordinated and proportional control of multiple prostheses functions.

B. Current status of studies leading to an evaluation of the feasibility of proportional prosthesis control by EMG signals.

Continuation of data analysis for preparation of an integrative technical report during the current fiscal year.

C. Current status of evaluation of surgical methods to establish new body control sites.

A report is in preparation summarizing the various phases and findings of the nerve relocation experiments on two monkeys.

D. Current status of experimental investigations assessing the various non-surgical methods to create proportional coordinated body control:

The experimental data collected to date are being integrated into a technical report during the current fiscal year.

II. COMPONENT DEVELOPMENT STUDIES

A. Objective

To evaluate existing prosthetic components and derive design criteria for further development or modifications.

B. Current status

Completion of data reduction will result in final report by June 1963 and termination of this phase.

Comments:

The work originally performed under this section was intended to explore the biomechanics of the human arm in order to obtain design specifications for prosthetic elbow flexion devices. One phase of this work was reported in Engineering Department Report No. 60-109 (Progress Report, December 15, 1960). This report contains a theoretical analysis of the muscles involved in elbow flexion in order to deduce certain torque-length relationships. It was felt that the theoretical analysis indicated that supplementary data on human subjects, using an "elbow dynamometer", would confirm the analysis, and lead to a more efficient design of prosthetic devices.

Eight subjects were tested on the elbow dynamometer and oscillograph records of time, force, elbow flexion angle and velocity were obtained. These records have now been completely analyzed and plotted. A report is in preparation. The report will integrate and discuss all work associated with the kinesiology of elbow flexion. A tentative title for the report is

"The Determination of Human Muscle Characteristics from Analysis of Experimental Elbow Flexion Torque Curves" and completion is expected by June 1963. It is expected that the report will terminate all aspects of this phase of the work.

III. CONTROL ENGINEERING SURVEY

A. Objective

Continuing compilation of systems and components and evelu-ations of their feasibility for use in externally-powered pros-theses.

Comments:

1. Potential state-of-the-art components are being catalogued from manufacturers' specification guides. Cataloging consists of grouping these components into functional categories which match current prosthetic components.

2. An attempt is being made to determine desirable component charactertistics based on a survey of characteristics of past and present prosthetic devices.

3. It is planned that results will be presented in the form of a matrix which will identify the functional and operational components of prosthetic devices and aid in establishing future trends.

IV. ANALYSIS OF EXISTING EXTERNALLY-POWERED PROSTHESES AND DEVELOPMENT OF ADVANCED DESIGN SPECIFICATIONS

A. Objective

To make an engineering and performance evaluation of existing

devices to assess their capabilities and limitations and derive specifications for further development.

B. <u>Current status of experimental investigations</u>

1. A final technical report summarizing all evaluation findings of the French Electric Hand is in progress.

2. Further delay has been encountered for both the engineering and functional evaluation of the Heidelberg pneumatic arm due to the current unavailability of necessary parts. All fabrication of prosthetic pneumatic components is now being handled by a commercial limb shop (Otto Bock, Duderstadt) and we have been advised that production of components has not started yet.

One new unilateral fore-quarter amputee has been procured as an experimental subject for performance evaluation. The amputee has been fitted with a Sierra pneumatic arm, but expressed dissatisfaction with its functional utility. Feasibility of conventional fitting is presently being explored. If conventional fitting is possible, the evaluation will take the form of comparing training time and difficulties as well as comparing functional adequacies as outlined in Biotechnology Laboratory Technical Note No. 27, 1963.

The Heidelberg pneumatic arm will be evaluated in two steps:

a. In its complete assembly with all three functions (elbow flexion, prehension, wrist rotation) externally powered.

b. In a modified assembly where only elbow flexion will be externally powered. Wrist rotation will be omitted and the terminal device will be body-powered.

Carl Sumida of CAPP assisted in all fitting and prosthesis modification work. Due to his efforts, the Heidelberg arm is in good working condition. However, in order to render its operation comparable to U.S. pneumatic arm developments and permit valid comparisons between these devices, new sequential switches must be obtained and are on order.

3. A methodology for evaluation of UE prosthetic systems has been developed and published as Biotechnology Laboratory Technical Note No. 27, 1963. Details of the technique and procedure for the evaluation of AE prostheses are now being developed.

4. Performance analysis of externally-powered elbow lift-and-lock systems: No reportable progress.

V. DEVELOPMENT OF ELECTRO-PNEUMATIC LOCK-AND-LIFT SYSTEM

A. Objective

Development of an externally-powered meet-the-load electro-pneumatic elbow flexion unit.

B. Current status

Report in preparation due byJune 1963, which will terminate this phase.

Comments:

The Progress Report for December 15, 1962 indicated that laboratory tests were to be resumed after a long period of inactivity on this phase of the work. In preparing for additional tests it became obvious that the tests could supply very little significant data.

The bench model which was to be used was put together to

investigate meet-the-load characteristics as well as "variable-ratio load coupling" between the power source and elbow load-lifting capability. The use of braided pneumatic activators (BPA) as the power source was only incidental to investigating the concepts mentioned. However, because they were used as power, they resulted in additional electronic and pneumatic circuitry which was particular only to BPA's and hence did not adequately reflect general principles in achieving "meet-the-load" requirements. Meeting the load is merely arranging for a delay mechanism which will preclude the application of sufficient force prior to unlocking the elbow flexion mechanisms.

The variable ratio coupling is also essentially independent of the means of applying power. The concept, as it was used in this phase of the work, was only concerned with the mechanical means for achieving the maximum efficiency between some linear cable pull and the resulting angular rotation of the elbow. Laboratory personnel directly concerned with the theory behind obtaining variable ratio coupling, envisioned the use of special mathematically computed cams which would be used in the elbow flexion unit. Unfortunately, none of the cams designed were ever used in the elbow unit and the personnel involved are no longer associated with the work.

A rationale of the situation indicates that it would be possible to conduct a series of experiments based on the use of various cams in the elbow unit but that under present conditions such a procedure would not be advisable due to a lack of ultimate utility. Therefore, since both "meet-the-load" and "variable ratio coupling" cannot be

adequately investigated with the present test set-up, it has been decided to prepare a report which will summarize all previous work associated with this phase. The report is planned for completion byJune 1963 and is tentatively entitled "An Analysis of Externally-Powered Elbow Lock-and-Lift System Using the Braided Pneumatic Actuator".

RESEARCH ON THE PERFORMANCE OF

HUMAN OPERATORS OF TRACKING SYSTEMS

Sponsor: U. S. Naval Ordnance

I. PERFORMANCE EVALUATION OF VARIABLES OF THE OPTICAL SYSTEM ON THE NOTS TRACKING SIMULATOR

A. Objective

Systematic evaluation of variables of the optical system on target acquisition and tracking accuracy. Design specifications for optimum performance shall be derived. Handbooks or tables will be ultimately developed to aid tracking system designers.

B. Current status of experimental investigations

Phase 1: Experimental investigation on the NOTS Tracking Simulator.

Data reduction and analysis of the experimental investigation described in previous progress reports has been essentially completed. The study was designed to investigate the importance of TV vs. monocular viewing displays and on-mount vs. off-mount proprioceptive cues for tracking performance. The interaction of the viewing modes with variations in the target trajectory, fields of view and magnification, and system driving dynamics were observed. The results can be briefly summarized as follows:

a. The monocular viewing mode is superior to both the

TV viewing modes while on-mount TV is superior to off-mount. This indicates both the superiority of the monocular viewing display and the importance of proprioceptive cues for tracking performance.

b. Tracking with the smooth trajectory is superior to tracking with a trajectory which changes direction and velocity rapidly.

c. The 5 degree, 5X monocular display is superior to the 13 degree, 1X monocular.

d. The rate plus displacement dynamics produced better performance than the pure rate dynamics.

e. Tracking is superior when the target moves from left to right than when it moves from right to left; tracking in the elevation dimension is superior to azimuth dimension tracking.

Comments:

These results were obtained from analysis of data from the Integrated Error Scoring System. Additional taped data from the Sampled Error Scoring System are currently being analyzed and a technical report is in preparation based on the data of the two error systems.

Phase 2: Equipment design and modifications

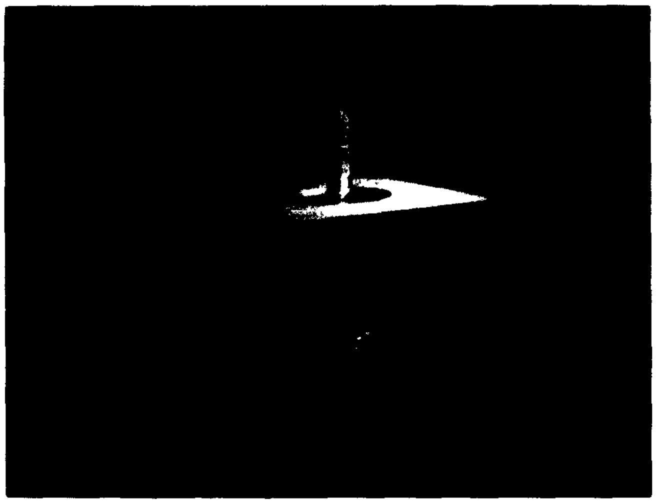
During the last quarter a new controller was designed and constructed. This "linear" controller is shown in Fig. 1 and is presently undergoing preliminary tests. It is

essentially a joy stick where the curvilinear motions of the stick have been transformed into linear motions, i.e., the linear stick remains perpendicular to the controller base and operates in two dimensions. This has been accomplished by the use of a ball-joint spring mechanism between the joy stick and the linear stick, thus allowing each to move in its "natural" directions. The purpose of the linear controller is an attempt to maximize display-control compatibility, especially when the display is a TV monitor.

Insert Figure 1 about here

A target acquisition aid has been developed and is under construction. It represents an attempt to facilitate initial target acquisition and reacquisition should the target be lost during a run. The display will consist of 133 pairs of lamps arranged in seven rows of 19 pairs; a row corresponds to a 10° change in elevation and a column represents a 10° change in azimuth. Each lamp of a pair will be electromechanically coupled to the controller and target trajectory so that, in effect, it is analogous to a "discrete" pursuit display, i.e., mount and target position information will always be available.

In practical applications the target and acquisition display obviously cannot be directly coupled. Use of a radar unit or an infrared sensing system would be necessary



LINEAR TRACKING CONTROLLER

FIGURE 1

to transmit target information to the display. It is expected that with such a combined system the operator could be "on target" long before he is able to see it through the optical system. Once acquisition is accomplished, tracking would be resumed through the conventional display mode.

Comment:

Construction of the linear controller made it possible to conduct some pilot tests on multiman parallel tracking with the simulator. Initial tests suggest a marked performance superiority over single man tracking. The evidence is not conclusive, however.

Phase 3: Literature review

An extensive review of the pertinent literature has been undertaken, particularly concerning the problems of error magnification, field of view, alternate presentation of data, (i.e., switching between two viewing conditions), system drive dynamics (aiding) and the effects of velocity and acceleration on tracking performance.

II. MULTIMAN TRACKING STUDIES

A. Objective

Investigation of the operating characteristics of tracking teams are expected to be developed.

B. Current status of experimental investigations

The previous progress report stated the experimental design to be employed in the present study in addition to some comments

on the experimental apparatus. The study has progressed as follows:

1. Experimental apparatus

A block diagram of the current experimental setup is illustrated in Fig. 2. With this setup the first tracker's

Insert Figure 2 about here

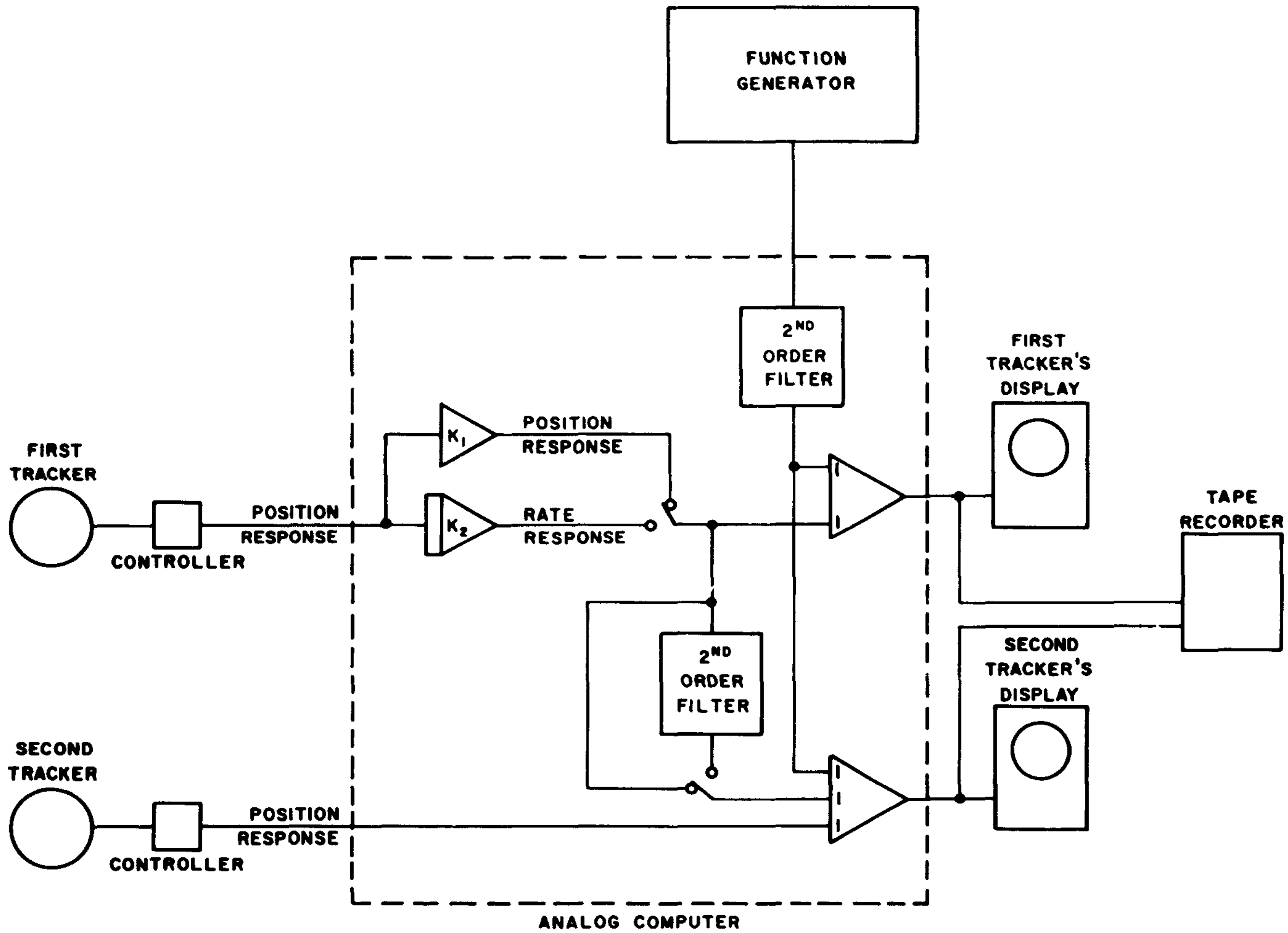
response can either be integrated so that the tracker's positioning responses are translated into oscilloscope cursor velocity rather than position or transferred unaltered other than by amplification. In addition, the first tracker's response may be filtered before it is combined with the original function and presented to the second tracker as an input function.

The functions as performed by the analog computer as indicated in Fig. 3 can be readily changed. Therefore, many

Insert Figure 3 about here

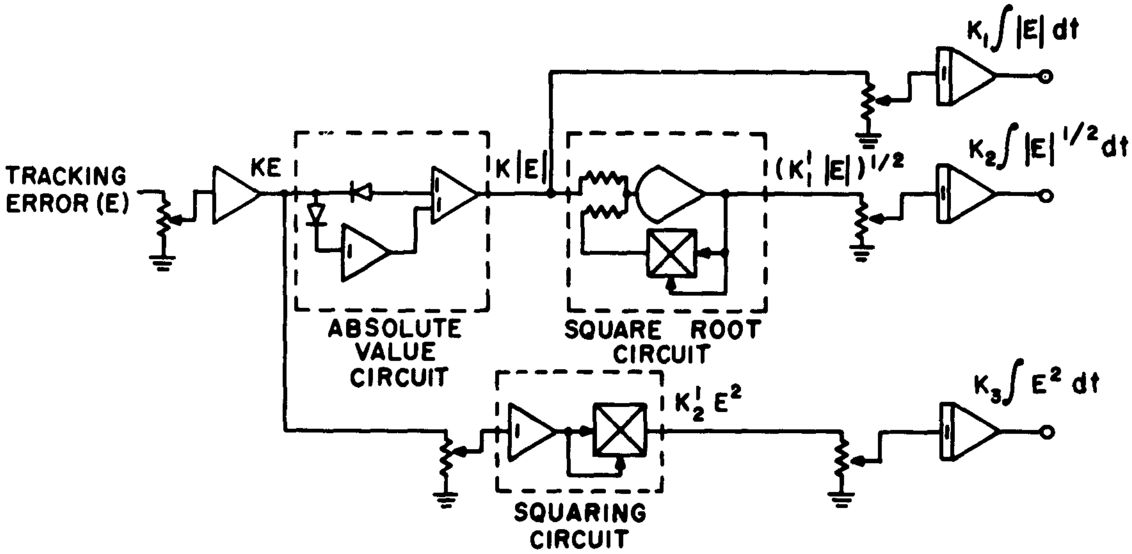
studies with different configurations of interaction between two trackers can be simulated with the present equipment.

The electronic difficulties mentioned in the previous progress report were traced to the manner in which the analog computer was programmed. It was possible to eliminate the resulting system instability by placing low capacity feedback capacitors across some of the critical operational amplifiers used in the present system configuration. These capacitors prevent high frequency oscillation.



BLOCK DIAGRAM OF TEAM TRACKING SYSTEM

FIGURE 2



ANALOG COMPUTER DIAGRAM OF DATA REDUCTION PROGRAM

FIGURE 3

The system as a whole, with exception of the tape recorder, has been checked out and is ready for experimental runs. Check-out of the tape recorder is now in progress through the use of analog computer data reduction programs as well as other means.

2. Preliminary tracking studies

In order to find a fairly optimum control gain for the rate tracking mode of the present study, a preliminary single tracker study was run in which subjects operated a velocity controller with a gain of either .031, .21, or 2.6 inches per second of oscilloscope cursor velocity per degree displacement of a joy stick controller. As a control, the subjects also tracked with a position type controller with a gain of .16 inches of oscilloscope displacement per degree displacement of the controller.

The tracking system illustrated in Fig. 2 was used. In the present situation the second tracker was absent and the first tracker operated in either the position response or rate response modes.

Two bidimensional input functions of unequal difficulty were employed in the preliminary study. The function generator and its unfiltered output are described elsewhere.[1]

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[1] Weltman, Gershon. "System Variables Affecting Team Performance in a Visual Tracking Task." UCLA Department of Engineering, November 1962

In the present situation the X and Y function generator filters were set at a cut-off frequency (f_o) of about $\frac{1}{2}$ cps for the simpler function and about .8 cps for the more difficult function. Time exposure photographs of the oscilloscope traces of these two functions appear in Fig. 4.

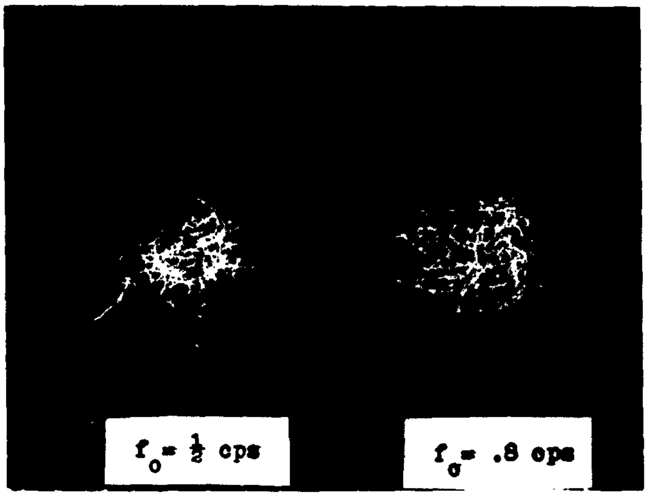
<u>Insert Figure 4 about here</u>

The results for both functions were about the same, with the simpler function resulting in less tracking error. Also, the results for the Y component and X component of the tracking error were similar. In Fig. 5 the oscillographic records

<u>Insert Figure 5 about here</u>

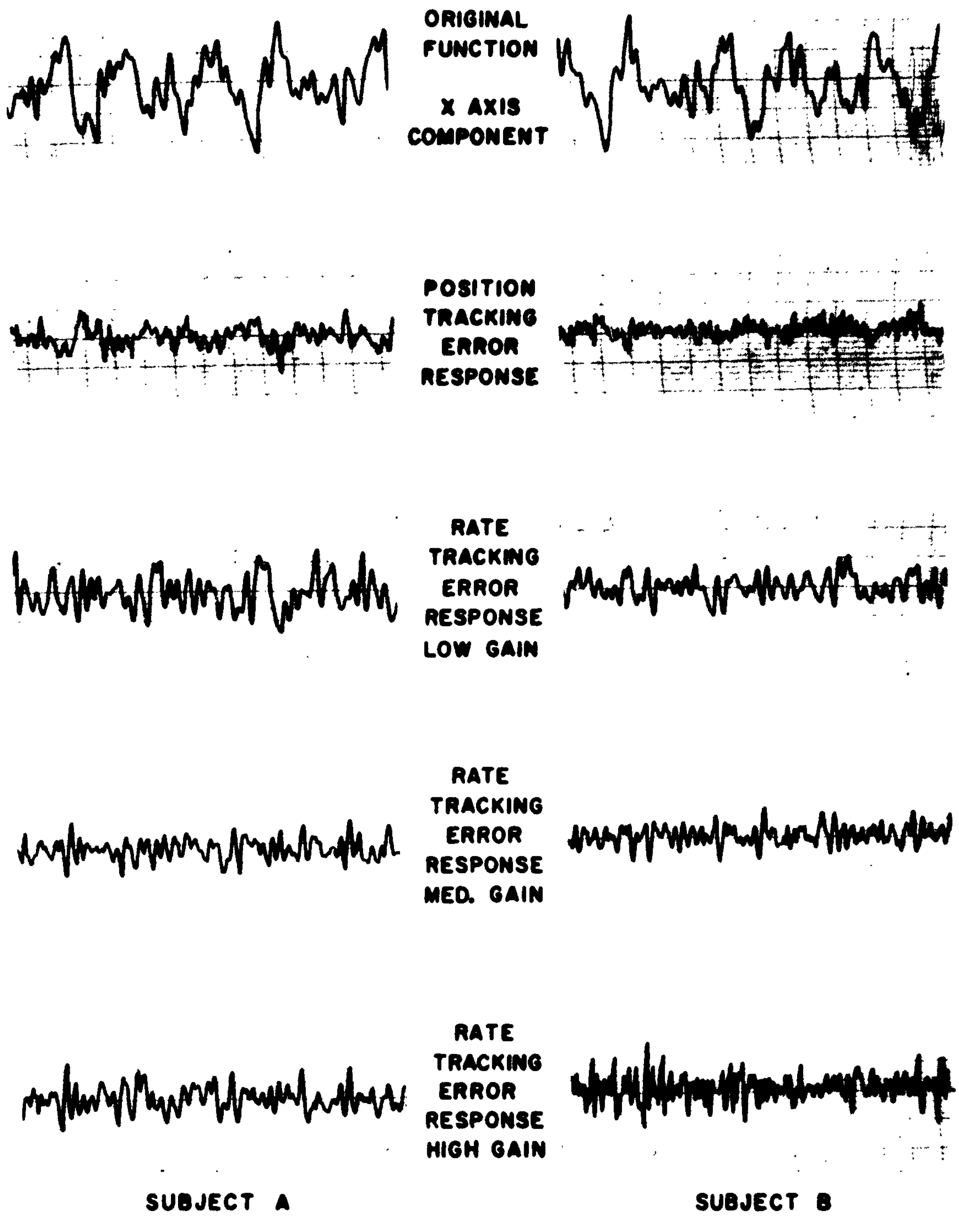
of the Y axis error score of two subjects are illustrated. In both cases the frequency output of the tracker is noted to increase with increasing rate gain. The position controller mode gave the highest frequency outputs, however. Also, the lowest rate gain gave the worst performance when integrated error was considered.

The optimum rate control gain, then, represents the payoff between minimizing frequency outputs and minimizing tracking error. To some extent this optimum depends both on the tracker producing the output and the second tracker, who tries to improve on the first tracker's error function. For present purposes, however, a rate gain between the low and medium gains considered in the above experiment seems justified, since in this region the frequency output of the tracker



TIME EXPOSURE PHOTOGRAPH OF TRACKING SYSTEM INPUT FUNCTIONS

FIGURE 4



RATE AND POSITION TRACKING ERROR RESPONSES OF TWO SUBJECTS

FIGURE 5

is not much higher than the frequencies in the original function and, in addition, the error scores are not excessive.

It is interesting to note that tracker B's frequency output is higher than that of tracker A. This result might well cause team member compatibility problems in the main experiment, and cause a wide variation in the performance from team to team.

3. Data reduction

It was mentioned previously that mean squared error of the final system output is to be used as a criterion measure in the main experiment. In addition to this, it was found to be desirable to set up an analog computer program which would also yield integrated absolute error and integrated square root of absolute error. Thus, besides getting a weighted view of large error excursions which would result from mean squared error analysis alone, we can also assess the importance of the large excusions. The analog computer diagram for the data reduction program is illustrated in Fig. 3.

III. LITERATURE REVIEW: AN INTEGRATION OF VARIOUS AREAS OF VISUAL PERCEPTION APPLICABLE TO TARGET ACQUISITION AND TRACKING PROBLEMS

A. <u>Objective</u>

To formulate testable hypotheses for investigations of the effects of the total field of view and frames of reference on target acquisition and following.

B. <u>Current status of review</u>: No reportable progress.

IV. SUMMARY OF ACCOMPLISHMENTS DURING CONTRACT PERIOD, JUNE 1, 1961 TO MARCH 30, 1963

The following summary of contract accomplishments is included because the present contract will terminate on March 30, 1963.

A. Experimental investigations on the NOTS Tracking Simulator

Two experiments were performed during the contract period. Experiment I was designed to assess the effects of three optical viewing displays on tracking performance;

1. Monocular, 5° field of view, 5X magnification
2. Monocular, 13° field of view, 1X magnification
3. Switching between these displays

Experiment II was designed to evaluate the importance of:

1. TV vs. monocular viewing displays
2. Proprioceptive cues when using a TV display
3. Interactions of display mode with systems dynamics

Comments:

Data reduction and analysis is essentially complete for both experiments and Technical Reports are currently in preparation. These reports should become available by the end of April, 1963.

B. Equipment modification

During the contract period the tracking system has undergone considerable modification:

1. The error recording system has been completely redesigned. There are now two independent measures of tracking

error available. The first system is the Integrated Error Scoring System (I.E.S.S.), where the error is sampled 24 times per second and integrated over a full tracking run. The result is displayed on a visual display system and read out on a totalizing counter. Independent records are made of the azimuth and elevation tracking dimensions. The second system is the Sampled Error Scoring System (S.E.S.S.), where the sampled records are recorded on a seven-channel tape. The data on these channels are pulses representing a reference pulse, error pulses in the two tracking dimensions and one of the set of pulses representing instantaneous mount position, mount velocity or controller position in each dimension. An audio identification and a 12.5 kilocycle timing sine wave are also recorded on the tape. These analog pulses are converted to digital information by NODAC at NOTS, China Lake, California.

A computer program for analyzing this data has been written and the data collected using the S.E.S.S. is now being reduced. The program will compute average and root mean square errors, records of the instantaneous error, trajectory position, mount position, velocity, and acceleration for each sampling point and a table of Time on Target Scores for half degree error zones up to a maximum of three degrees from center. The results will be given

independently for the two dimensions and for the resultant scores. A further program will yield graphic plots.

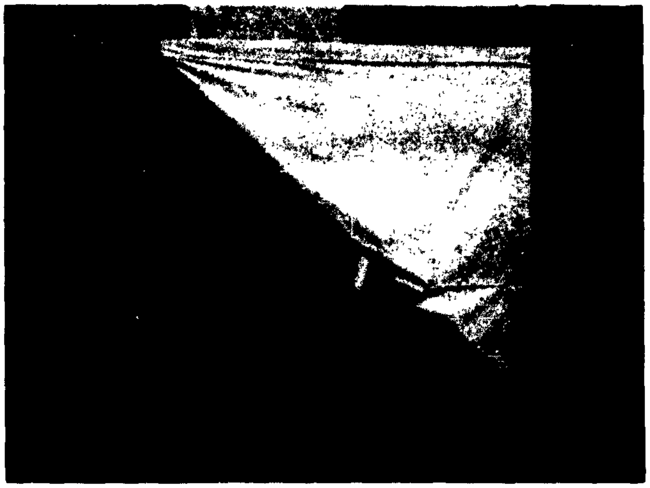
2. An isolation booth has been built for off-mount TV tracking and is illustrated in Fig. 6. Such factors as

Insert Figure 6 about here

chair and controller position, parallax due to differences in head position, and the subject's comfort can be readily controlled. The booth reproduces viewing parameters, such as viewing angle, found in the on-mount TV tracking position. The booth is portable and can be placed in any orientation with respect to the Tracking Simulator.

3. The problems of running the complicated tape deck utilized for the S.E.S.S. in the experimental scoring system where very little light is available has been solved by the development of a timing-switching mechanism. The timer operates a complete subject run automatically. A $\frac{1}{2}$ rpm motor drives seven adjustable cams which start and stop the sequence, turn the tape recorder on and off, and operate the target trajectory system.

4. A target trajectory device using a new approach has been developed during the past year. The system consists of a trajectory inked on a scale model shell of the tracking quartersphere which is followed by photo-cell pickups connected to a small mirror so as to project the light spot onto the quartersphere in the prescribed trajectory. This



TRACKING ISOLATION BOOTH

FIGURE 6

system will offer variability in the path of the trajectory as well as in the trajectory velocity and acceleration. The system is currently undergoing installation and testing and, if found satisfactory, will be used in forthcoming experiments.

5. A new linear controller and an acquisition display are under development.

Comment: Each of these modifications, as well as a full description of the complete UCLA tracking system, is given in detail in a Technical Report by Howard, Kreifeldt and Garfinkle (1963). In addition, the trajectory device will be fully described in a master's thesis by Amtmann, which is currently in preparation.

C. Literature review

An extensive literature search pertaining to the variables selected for experimental investigation has been conducted. The findings will be integrated with empirical data and discussed in the relevatn Technical Reports.

C. Multi-man tracking studies

This investigation was conducted for evaluating the merits of dividing the tracking task between two operators and attempting to evolve optimum configurations of systems parameters. Both uni-dimensional and two-dimensional input problems were examined. Some of the more general findings can be summarized as follows:

1. If systems parameters are carefully chosen, the two-men

team performs consistently and substantially better than the single tracker.

2. Team performance was found to be superior to tracking performance of the better team member for complex tasks. Performance over the "average" team member was improved by about 30% and over the better team member by about 18%.

3. For certain conditions, response-sharing tactics were found and for others, response-dominance was evident. In the dominance situation, one team member contributed little to nothing to the team output.

More extended studies will be necessary before optimization of system parameters as, for example, controller gains and display magnification can be achieved. Specifically, the following extensions seem to be indicated: (1) consideration of tracking studies incorporating commonly used controlled-system dynamics and control modes, (2) inclusion of more difficult tracking tasks, and (3) use of a more extensive and heterogeneous operator population.

Work in progress examines two possibilities for eliminating high frequency noise introduced into the tracking task by the lead tracker in the serial configuration: (1) providing the lead tracker with a rate control, (2) filtering of the lead tracker's response.

E. Investigation of the characteristics of the human operators in a control system

The study was concerned with the mathematical representation of the input-output behavior of the human operator in a compensatory tracking system. Mathematical models which are commonly used to represent the human operator in such a system consist of linear differential equations whose coefficients depend on the bandwidth of the input signal and on the dynamics of the controlled processes.

The major objective of this study was to examine a new class of mathematical models of the human operator which are based on discrete operations and were hypothesized to predict compensatory tracking performance more accurately. Input-output relationships, i.e., transfer behavior were developed and described in mathematical terms so they would be useful for the analysis and synthesis of man-machine control systems.

Results of the study showed that for the tracking situation investigated, the sampled-data models predicted an input-output analysis of tracking behavior that approximated the obtained experimental data more closely than could be achieved with any of the linear continuous models.

The study has placed major emphasis on the utility of the measurement of the error spectral density in human tracking as a sensitive indicator of tracking performance.

The following extensions of this area of research were suggested by the results of the study:

1. Investigations of pursuit tracking and two-dimensional tracking.

2. Variations in the model for adaptation to changes in task difficulty during the course of any given tracking task.

F. Project publications 1961 - 1963

J. G. Kreifeldt. "Position-indicating Circuitry for the 40mm Tracking Mount". Rep. No. 61-53, 1961, Dept. of Engr., UCLA

J. Howard, J. G. Kreifeldt, D. Garfinkle. "System Description of the Human Tracking Installation at UCLA", in press, Dept. of Engr., UCLA.

G. A. Bekey. "Investigation of Sampled Data Models of the Human Operator in a Control System". Rep. No. 62-6, Dept. of Engr., UCLA.

G. Weltman. "System Variables Affecting Team Performance in a Visual Task". Rep. No. 62-59, 1962, Dept. of Engr., UCLA.

D. Garfinkle, R. Smith, K. Ziedman. Tentative title: "An Investigation of Performance Changes As Affected by Selective Optical Systems Variables, Control Systems Dynamics and Proprioceptive Cues". In preparation.

RESEARCH ON

SENSORY-MOTOR CONTROL

Sponsor: Office of Vocational Rehabilitation

A. Objective

To conduct basic and applied research on arm prostheses sensory-motor control problems and undertake analyses and evaluations of prosthesis-amputee systems. The objective of the research is to develop engineering design criteria for advanced prosthetic systems.

B. Current status

1. Evaluation of the AIPR pneumatic arm:

One AE pneumatic prosthesis has been received from AIPR and served for getting acquainted with the system. Since the first test amputee is a bilateral AE, plans have been made for a bilateral analysis.

Although fitting and harnessing is being done by Mr. Sumida of CAPP, the custom-made forearm units must be obtained from AIPR. At present we are waiting for a requested shipment of:

2 forearms

1 elbow mechanism

2 sets of pneumatic sequential control switches

2 pneumatic heavy-duty hooks

2 pneumatic light-duty hooks

2 pneumatic hands

Time delays are unavoidable under these circumstances. In the meantime, testing equipment and procedures have been developed, so that the experimental investigation can begin without additional delays.

Miss Dennis, Senior O.T. with CAPP, will supervise the training of the first subject with the AIPR pneumatic prostheses.

2. Studies of mechanical properties of isolated muscle bulges, in order to assess their suitability for control of coordinated multiple prostheses functions, are in the planning stage.

PROFESSIONAL ACTIVITIES OF STAFF MEMBERS

January 24:

Dr. Lyman addressed the Air Force Industry Conference on Materiels Handling Equipment at Riverside, California. Topic: "Use of Simulators for Systems Evaluation."

February 2:

Visiting engineers attending the Industrial Engineering Institute at UCLA visited the Biotechnology Laboratory.

February 4-8:

Dr. John Lyman attended the 1963 lectures on Aerospace Medicine at Brooks Air Force Base, San Antonio, Texas.

March 11:

Dr. Lyman and Dr. Hilde Groth addressed a meeting of the Society of Orthotists and Prosthetists on the subject of "Advanced External Power for Prosthetics and Orthotics".

March 14-16:

Dr. Lyman served as speaker and panel member at the Conference on Rehabilitation, held by the National Academy of Science Committee on the Skeletal System, held in Washington, D. C. Topic: "Human Factors in the Control of External Power".

PUBLICATIONS

H. Groth, J. Lyman, and P. K. Kaiser

"Rationale and Methodology for Evaluation of Upper Extremity Prosthetic Systems", Biotechnology Laboratory Technical Note No. 27 (UCLA Engineering Department Report No. 63-13), March, 1963.

R. W. Allen and J. Lyman

"Arm Water Losses Under Disparate Arm and Body Thermal Conditions", November, 1962.

VISITORS TO THE LABORATORY

January 10:

C. C. Sansom, Military Relations, Lockheed Missiles and Space Company, Sunnyvale, Calif.

Dr. Robert L. Martindale, Lockheed Missiles and Space Company, Sunnyvale, Calif.

February 18 and 19:

Design and Development Sub-committee of CPRD

Professor Charles W. Radcliffe, Northwestern University, Chicago, Ill.

Dr. Fred Leonard, Director, U.S. Army Prosthetics Research, Walter Reed Army Medical Center, Forest Glen Section, Washington, D.C.

Mr. Anthony Staros, Veterans Administration, New York, N. Y.

Mr. C. A. McLaurin, Prosthetic Research Center, Northwestern University, Chicago, Ill.

March 1:

Dr. Don Young, Physiologist, NASA, Moffett Field, Palo Alto, Calif.

March 13:

Dr. Albert Hall, International Business Machines Corporation, San Jose, Calif.